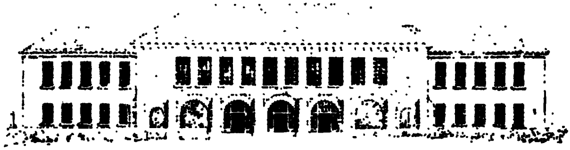
SIMPLE EXPERIMENTS

OR THE SCHOOL ROOM

JOHN F. WOODHULL



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No. 9.

SIMPLE EXPERIMENTS

FOR THE

SCHOOL-ROOM:

THAT MAY BE MADE BY TEACHERS WHOLLY WITHOUT PREVIOUS EXPERIENCE;

AND ADAPTED TO INTRODUCE YOUNG PUPILS TO A KNOWLEDGE OF ELEMENTARY SCIENCE BY EXPERIMENTAL METHODS, AND AROUSE A SPIRIT OF INQUIRY.

BY

JOHN F. WOODHULL,

Professor of Natural Science in the College for the Training of Teachers, New York City;
Author of "Manual of Home-made Apparatus."

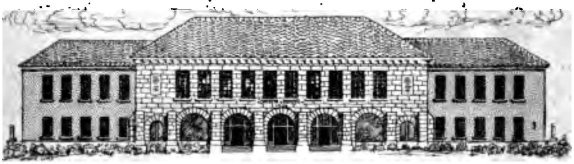
NEW YORK AND CHICAGO:

E. L. KELLOGG & CO

1892.

PREFACE.

It is a duty the teacher owes to his pupils to explain to them, or enable them to find out, the causes of the ordinary phenomena that daily happen before their very eyes. This is the object the experiments detailed in this book aim at. They can be performed by any teacher in a common district-school as well as in a graded school. That the experiments are entirely practicable is proven by the fact that they are daily performed by the author's pupils in the College for the Training of Teachers, New York City. The most feasible plan will be for the teacher, or one of the older pupils, to perform the experiments in the presence of the class, and then elicit their observations and inferences by questions. Their answers will frequently suggest the advisability of repeating experiments several times, and the experienced teacher will feel called upon to bring in many allied topics not mentioned in this book. Treating the subject in this way, the author has found that the book suggests work enough to occupy a grammar-school class two periods a week for a whole year.



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CHAPTER IV.

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APPENDIX.

SIMPLE EXPERIMENTS.

FOR THE SCHOOL ROOM.

Chapter I.

PRODUCTS OF INCOMPLETE COMBUSTION.

SECTION I.

EXPERIMENTS WITH PAPER.

Experiment 1. We lighted an old-fashioned "lamp-lighter," and noticed that a strange tongue of flame continued to burn at the lower end, while the original flame crept slowly toward the upper end, the two flames being separated by the charred portion (Fig. 1).

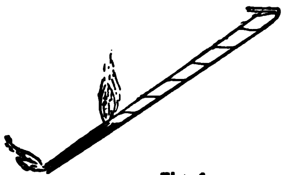

Fig. 1

We blew out the tongue of flame at the lower end, allowing the other flame to go on burning, and noticed that a stream of gray smoke poured from the lower end, which sprang into flame when a lighted match was brought near.

Combustible Smoke from "Lamp-lighter."

Note.—The "lamp-lighter" was made from a strip of newspaper, about eighteen inches long and one and a half inches wide, coiled into a tube about as large in di-

ameter as a lead-pencil, and nine or ten inches long. The upper end was folded over to keep it from unwinding. The lower end was left open.

Experiment 2. We coiled another "lamp-lighter" and left both ends open, holding it near the upper end between the thumb and finger to keep it from uncoiling, and lighted it as before.

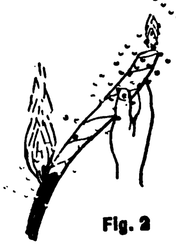

Fig. 2

In this case there was no tongue of flame at the lower end, but the smoke poured from the upper end in sufficient quantity to support a flame for an instant without burning the paper (Fig. 2).

Note.—The experiment succeeded best when we were careful to keep away from it all draughts of air.

It was also found to work better when we used a little thicker paper, such as writing-paper or brown wrapping-paper, and were careful to roll it so as to make a clear tube with both ends open.

When the flame had advanced about one and a half inches from the lower end we pinched the upper end, and the dense smoke began to pour from the lower end, which sprang into a large tongue of flame when a lighted match was brought near. When we ceased to pinch the upper end the flame died out below, and the gas began to pour from the top again, but when the upper end was pinched the tongue of flame appeared at the lower end once more.

Experiment 3. We coiled another "lamp-lighter," leaving both ends open, and burned it as before, but

when the flame approached rather near to the upper end, instead of blowing it out we inverted it, having the charred end uppermost, and allowed the flame to die out slowly of its own accord. Upon unrolling the end which remained unburned we found it stained inside with a yellow liquid.

Liquid Stains.

Experiment 4. We crumpled a sheet of writing-paper and burned it upon a white plate or clean surface of some kind, and noticed stains of the yellow liquid left upon the plate when the burning was ended.

Note.—In the primitive days of dentistry persons used to moisten cotton in this liquid, and put it into a hollow tooth to kill the nerve.

We also noticed during the above experiment that from certain portions of the paper smoke arose, which occasionally caught fire.

Experiment 5. We took a wide-mouthed bottle (Fig. 3) which chanced to be at hand (capacity of about eight ounces). We made a "lamp-lighter" as before, of a strip of foolscap paper, and left both ends open. When the flame had made its way about two inches we brought the charred end over the mouth of the bottle, and pinched the upper end, causing the smoke to pour into the bottle, which slowly filled it as if it were a liquid. When the bottle was full we thrust the burning "lamp-lighter" down into it until the flame entered the mouth. The smoke suddenly caught fire,

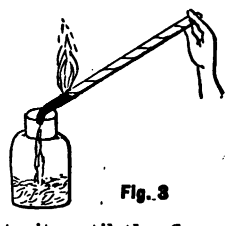

Fig. 3

and instantly burned up, leaving the bottle perfectly clear, whereas before it had been impossible to see through it on account of the dense smoke.

Experiment 6. Again we caused the smoke to pour into the bottle as before, filling it this time about three-fourths full (Fig. 4), and then laid a small piece of paper over the mouth to keep away draughts of air. The upper surface of the smoke formed a distinct dividing line between it and the air which was in the upper fourth of the bottle. In eight minutes the smoke had about disappeared, and the bottle was then almost clear, except that the bottom and sides appeared to be slightly tinged yellow, as if some of the liquid noticed in Ex. 3 had been deposited when the smoke condensed. We now brought a flame into the bottle, and there appeared to be no gas inside to burn.

Fig. 4

Smoke Condensable.

Experiment 7. We filled a bottle with the smoky vapor,* as before, and allowed it to condense, repeating it six times until enough of the liquid gathered on the bottom of the bottle to form several drops, which flowed about as we tipped the bottle from side to side.

Liquid obtained from the smoke, vapor.

Note.—In filling the bottle several times with the vapor we found it to be best to close the upper end of

* We call it vapor, because we have evidence that it may condense to a liquid.

the "lamp-lighter" by folding it over, and begin by lighting it about one third the way up from the lower end. The vapor poured from the lower end in a large stream, and if we brought it against the inside of the bottle the cold glass condensed a portion of the vapor into drops of liquid quite rapidly.

Flashing temperature.

Experiment 8. We noticed that the vapor would take fire only while hot. We spent about half a minute in filling the bottle, and found that if we brought a flame into it within one minute and a quarter after that, a flash of light would occur, but when we waited longer it refused to burn. We judged that it cooled below its flashing point in about one minute and a half.

Vaporizing temperature.

Experiment 9. We took the bottle in which a few drops of liquid had been formed, and heated it by setting it in a basin of water and bringing it over a flame.* We caused the water to boil, but failed to vaporize the liquid. We brought a flame into the bottle but no flash occurred. It appeared to require a higher heat than that of boiling water to change the liquid into the vapor state.

Experiment 10. We collected some of the liquid in a

* If one uses an alcohol lamp to furnish heat for experiments, a very convenient support for the object to be heated is an ox-muzzle inverted over the lamp, or a stiff wire sieve, or a tin pail with holes in it, or anything similar, which may be most accessible. See Fig. 6.

small tin box—spice-box—and heated it over a flame without the basin of water. Dense clouds of gray smoke arose, which caught fire when a flame was brought near. After the smoke had ceased to rise, the box was removed from the lamp, and in place of the liquid were found black specks, which appeared like charcoal. The characteristic odor had entirely disappeared, and the blackened residue was tasteless, odorless, and insoluble in water or alcohol.

The liquid vaporized, but decomposed.

Experiment 11. We crowded some paper into a tin box and heated it over a flame. Large quantities of smoke arose from the heated paper, which caught fire when a flame was brought near. While the flame was allowed to burn inside of the box no smoke arose, but when the flame was extinguished * the smoke poured forth in large volumes again.

We brought a clean piece of broken window-glass into the smoke which was rising from the box, and large drops of liquid condensed upon the glass. We continued to heat the paper for about two hours, and after the vapor ceased to rise we noticed that the charred paper glowed and slowly wasted away, but would not support a flame when we tried to light it. At last the blackness all disappeared, and an exceedingly small quantity of ashes remained, which were white.

Mineral matter in paper.

We arranged an apparatus for catching the solid,

* We found that the easiest way to extinguish the flame was to lay a piece of paper, or something, over the box. This suggests a line of experiments which will be taken up in Chapter III.

liquid, and gaseous products separately, as shown in Fig. 5, in order that we might study them more completely.

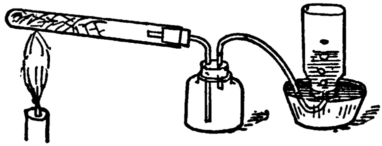

Fig. 5

The scope of this book will not permit of a description of the experiment here, but it is worth while to remark, that among the products volatilized by heat was found a gas which did not condense to a liquid, though we caused it to bubble through water, and which burned with a blue flame after being completely cooled.

Experiment 12. We filled a bottle with the vapor, and poured it into another similar bottle as we would a liquid. We poured it from the first bottle through a funnel into a narrow-mouthed bottle. We siphoned it through a tube.

The vapor heavy

Experiment 13. The liquid which stained the sides of the bottle did not wash off easily in water, but when we put a teaspoonful of alcohol into the bottle it all dissolved readily, forming an amber-colored fluid.

Solubility of the liquid.

General Conclusions from "Lamp-Lighter" Experiments—Products of Incomplete Combustion.—1. A combustible vapor is formed when paper is heated to

Gaseous products.

a high degree without inflaming. The flame which one sees upon burning paper is fed by this combustible vapor.

Liquid products.

2. A viscid liquid is formed when paper is heated to a moderate degree without burning, but at a higher heat this liquid breaks up into gases and a black residue—carbon.

Solid products.

3. When paper is heated moderately, a black residue is left, which nearly preserves the original form of the paper; but this may be heated sufficiently in air to cause the blackness to disappear and only a very small quantity of ashes remain, which are white.

SECTION II.

EXPERIMENTS WITH WOOD.

Experiment 14. We lighted a slender stick of wood about half an inch in diameter and noticed little tongues of flame shooting out from the end and at various points along the side, which suggested the tongue of flame at the end of the "lamp-lighter" in Experiment 1. Occasionally a little jet of flame would go out and a small stream of smoke would pour from the place where the flame had been, and perhaps this would by chance be wafted toward a little neighboring flame and get re-lighted again. The tongues of flame are sometimes very noticeable in a burning match. Also, if the burning end is held uppermost a liquid may be seen to come out of the wood.

Experiment 15. We took a tin box—it chanced to be a baking-powder box of half a pound capacity (Fig. 6). We put into it a handful of slivers of wood and heated them over our lamp, determining to see if a combustible vapor could be obtained. A gray smoke began to arise from the box immediately, which looked very much like that already obtained from the "lamp-lighter." When a lighted match was brought to the top of the box the gray smoke caught fire, and a flame flashed down into the box, but went out immediately. Forthwith some more smoke filled the box, and was again tested with a lighted match, with the same result as before. After a short time, however, the smoke came so fast as to support a flame continuously.

Fig. 6

Combustible smoke from wood.

Experiment 16. While it was thus burning we laid a piece of broken window-glass over the box, and immediately the flame was extinguished; but the smoke began to condense upon the glass, and soon we had it well covered with a watery liquid interspersed with drops of a dark-brown liquid. The glass being heated still farther the watery liquid was dissipated, and the dark-brown liquid became hard and glossy like a varnish. After a time the vapor ceased to flow, the atmosphere of the box cleared up, and we took away the lamp. In the box we found as nice specimens of charcoal as could be desired.

Liquid obtained from the smoke, vapor.

Manufacture of charcoal.

We had thus procured from the wood (1) a combustible vapor, (2) a liquid, (3) a black solid. We made a further study of the liquid products.

Experiment 17. We filled the box about half full of slivers of wood, and placed it over the flame and inverted a tumbler over it, supported upon two slivers laid across the top of the box (Fig. 7). At first a considerable quantity of steam gathered upon the inner walls of the tumbler, and collecting into drops of water ran down the sides.

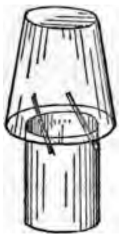

Fig. 7

But soon the tumbler was well filled with a dense gray vapor, which we tried to inflame, but it declined to burn—perhaps because it was cooled below its flashing-point; for when we brought a lighted match to the mouth of the box the vapor arising therefrom caught fire.

We replaced the tumbler, and the vapors collecting inside condensed into drops of yellow liquid very rapidly, and trickled down the surface of the glass.

In a few moments we removed this tumbler from the box and turned its mouth upward, gathering the drops of liquid in the bottom, and then put a clean tumbler in its place over the box. As the experiment proceeded farther it was noticeable that two kinds of liquid were formed, which did not incline to mix with one another. The first was thin and light colored; the other, thick, and of a very dark-brown color.

Two kinds of liquid.

Experiment 18. We put a drop of the thin liquid on

some litmus-paper.* It made a red spot. We did the same with a drop of vinegar, lemon-juice, and many other substances which we call acids. In each case the litmus-paper was spotted red. The liquid from the wood was found to be an acid, which we may properly call "Burnt-wood acid."

Acid properties of the liquid.

Experiment 19. The liquid was put into a small tin box and heated as in Experiment 10. Dense clouds of gray smoke arose, which caught fire when a flame was brought near. After the smoke had ceased to rise the box was removed from the lamp, and in place of the liquid were found black specks, which appeared like charcoal.

The liquid vaporized, but decomposed.

The characteristic odor had entirely disappeared, and the blackened residue was tasteless, odorless, and insoluble in water or alcohol.

Experiment 20. The liquid stains in the tumbler did not easily wash off in water, but alcohol was used as in Experiment 13, with similar results.

Solubility of the liquid.

Experiment 21. We put the tin box, containing the charred slivers of wood which remained after Experiment 16, over the flame, and roasted them a long time. The tips of the slivers glowed with sparks of fire,

* Litmus may be procured in small cubes at ten cents an ounce. When this is boiled in water a deep-blue solution is formed. "Litmus-paper" may be prepared by dipping strips of unsized paper into this solution and allowing them to dry. We commonly use this paper to detect acids.

but no blaze was formed. We took out a sliver of the charcoal and held it directly in the flame. It grew red-hot and wasted away, but would not burn with a flame.

When we wafted more air into the box the slivers glowed more brightly. When we blew hard a flame appeared above them, which died out as soon as we stopped blowing.

The final result of the experiment was a quarter of a teaspoonful of gray ashes.

Ashes from the charcoal.

Experiment 22. Having obtained about a teaspoonful of ashes by the above method, we put them in a tin-box cover, and put about two table spoonfuls of water upon them, and heated them over our lamp for a few moments. Then letting the ashes settle to the bottom we poured off the clear liquid into a tumbler. This liquid made the fingers feel slippery, just as potash does. We touched a little to the tongue, and it had the taste peculiar to potash.

Lye from the ashes.

Experiment 23. We compared these ashes with the charcoal from which they came. The ashes had a peculiar taste, while the charcoal had none. The water in which ashes had been soaked had a peculiar taste, and imparted a peculiar feeling to the fingers. When acid was poured into it there was an effervescence: none of these things were true of water in which charcoal had been soaked.

Properties of the ashes compared with those of the charcoal from which they came.

Drinking-water is frequently filtered through char-

coal, but we would not care to drink water that was filtered through the ashes which come from burning that charcoal.

Experiment 24. We put a drop of the water in which the ashes were boiled (in Ex. 22), upon the red spot of the litmus-paper of Experiment 18, and it turned it blue again.

Alkaline properties of the ashes.

We tried similar experiments with ammonia water, lime-water, water which contained some saleratus in solution, and water into which we had put some potash. They all turned reddened litmus-paper blue.

We had obtained from the ashes a substance which had opposite properties from an acid—an alkali. Indeed we had some *potash* like that used in soap-making.

Soap-making.

When potash, soda, or lime is mixed with grease in the proper proportions and boiled a long time, soap is formed. The experiment was performed in the laboratory, but it is unnecessary to the present line of discussion, and therefore omitted from these notes.

We arranged apparatus as represented in Fig. 5, and obtained the same results with wood as with paper.

General Conclusions from Experiments with Wood—Products of Incomplete Combustion.—1. A combustible vapor is formed when wood is heated to a high degree without inflaming. The flame which one sees upon burning wood is fed by this combustible vapor.

Gaseous products.

2. A viscid liquid is formed when wood is heated to a moderate degree without burning, but at a higher heat this liquid breaks up into gases and a black residue—carbon.

Liquid products.

3. When wood is heated moderately, a black residue is left, which nearly preserves the original form of the wood; but this may be heated sufficiently in air to cause the blackness to disappear, and only a very small quantity of ashes remain, which are white.

Solid products.

SECTION III.

EXPERIMENTS WITH A CANDLE.

A tallow candle with a very large wick was found to succeed better than any other in the following experiments. Not being able to find such a candle in the market, we set out to make one.

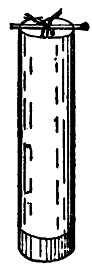

Fig. 8

Experiment 25. We took about four feet of candle-wick, folded it fourfold, and twisted it so that it was somewhat less than one foot long.

Making a candle.

We rolled a sheet of note-paper into a tube, somewhat over an inch in diameter, and tied a string around it to keep it from unrolling (Fig. 8).

We were careful to make the tube of such a size that a certain cork which chanced to be at hand would fit into the end of it. We fastened the candle-wick to the middle of the cork with a tack, and, passing the wick up through the tube, drew the cork into the lower end to close up the tube at the bottom.

We laid a sliver of wood across the top of the paper-tube and tied the wick to it. We then adjusted the wick so that it ran as near to the central line of the tube as possible.

Having some difficulty in finding tallow in the market, we purchased three quarters of a pound of fat beef or fat mutton, and cut it into small pieces and melted it in a half-pint tin cup. This is what is called "trying out the tallow."

"Trying out" tallow.

We skimmed out with a flat stick the pieces of connective-tissue which remained, and allowed the melted fat to cool a little so that it might thicken a trifle and be less liable to soak through the paper. We then poured it into our paper-mould and set it away to cool.

The next day we unrolled the paper, and had just such a candle as we desired.

We made a convenient support for it by taking a piece of card-board and pushing a pin up through it into the candle (Fig. 9).

In a similar manner we made candles of wax and of paraffine.

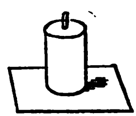

Fig. 9

Experiment 26. Whenever we blew out the candle-flame we noticed a stream of gray smoke pouring from the wick, similar in appearance to that which we had produced from the "lamp-lighter."

We held a lighted match a few inches above the wick *immediately* after blowing out the flame. The fire ran down the smoke and lighted the candle again. This succeeded when we held the match as much as five inches from the end of the wick.

Combustible smoke from a candle.

Experiment 27. We rolled up a paper tube about ten inches long and half an inch in diameter, and brought it over the wick immediately after blowing out the flame. This guided the smoke up, and we lighted it at the top. When we lifted the tube a little above the wick, the flame ran down inside and lighted the candle again.

We performed a similar experiment by bringing down over the wick a lamp-chimney instead of the paper-tube.

Experiment 28. We performed a similar experiment with the student's lamp. Directly after blowing out the flame a lighted match was brought to the top of the tall chimney; a flame ran down the stream of smoke and lighted the lamp.

Combustible smoke from a kerosene lamp.

Experiment 29. We held a splinter of wood across the flame of the candle just above the end of the wick. The wood was burned in two places (*a* and *b* Fig. 10), at the edges of the flame. A piece of white thread held across the flame in a similar manner was burned off in two places, and the short piece in the flame fell down upon the end of the wick unburned.

The dark centre of the flame.

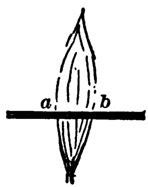

Fig. 10

Experiment 30. We held a piece of paper horizontally in the flame about a quarter of an inch above the wick. A black circle was burned into the paper by the outer edges of the flame (Fig. 11). The result was most striking when we took heavy writing-paper and held it in the

flame until a black circle appeared upon the upper surface. Then removing it quickly, we were able to break out a disk of unburned paper from within the black circle.

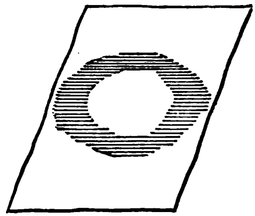

Fig. 11

Experiment 31. We made a thick-paper tube about a quarter of an inch in diameter and about six inches long. We then dipped it in water to prevent its catching fire easily.

With this paper tube we were able to conduct a combustible smoke out from the centre of the candle flame.

Holding the wet-paper tube in the hand we thrust the lower end into the centre of the flame, as represented in Fig. 12, the lower end being a quarter of an inch above the end of the wick. Immediately a dense gray smoke, similar in appearance to that which we had produced in previous experiments from burning "lamp-lighters," poured from the upper end of the tube, and when a lighted match was brought near it supported a flame.

Combustible smoke led from dark center of a candle flame.

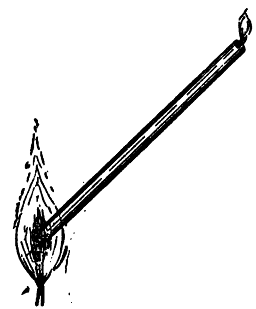

Fig. 12

The whole experiment was performed so quickly that the paper tube was withdrawn from the flame *before it caught fire.*

The experiment is more easily performed with a similar tube of glass or tin.

It is quite necessary to the success of the experiment that the flame should be broad and large.

With a bent-glass tube we led the smoke from the centre of a candle into a bottle. It appeared very much like the "lamp-lighter" smoke, and burned very readily when a lighted match was brought to the mouth of the bottle.

Tallow, etc., vaporized but decomposed.

Experiment 32. We put various substances of which candles are made, such as tallow, wax, and paraffine, into a tin box, and heated them over the lamp.

They melted, and after a time gave off gray smoke, which eventually sprang into flame of its own accord.

It was noticed that they turned dark colored while heating, as if they all had a tendency to char. See Ex. 86.

General Conclusions from Experiments with a Candle.—1. No solid products remained after the candle was burned. Leaving out of consideration the wick which was snuffed away, if any ashes were formed from the tallow they must have been so slight as to have been wafted away by the currents of air which always exist about a flame.

Solid products not detected.

2. The candle by its own heat is melted into a liquid which is contained in the cup at the top. This liquid is drawn up the wick as oil is drawn up the wick of a lamp.

Liquid formed by melting.

Gaseous products at higher temperatures.

3. The heat of the flame converts this liquid into a vapor which feeds the flame just as the flame of burning paper or wood is fed by vapor.

SECTION IV.

EXPERIMENTS WITH KEROSENE.

Experiment 33. We put a little kerosene into a tumbler and thrust a lighted match down into it; the match was extinguished. We attempted to light the oil upon its surface, but it refused to burn.

Extinguishing a flame with kerosene.

Experiment 34. We put one end of a piece of candle-wick or string into the oil, and let the other end hang over the side of the tumbler (Fig. 13). After the oil had soaked up the wick we lighted the upper end of it, and it burned very well; but when we lowered the burning wick down into the oil it went out.

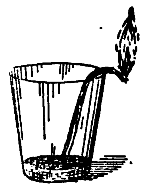

Fig. 13

Experiment 35. We put the oil in a cup and set it over the lamp, drawing down the wick of the lamp to make a small blaze, that we might heat it very gradually.

We frequently brought a lighted match over the mouth of the cup to see if a combustible vapor would be formed.

Combustible vapor from kerosene when heated.

When the oil had become moderately warm a flame from the lighted match flashed down into the cup, precisely as it did in the box where paper or wood was heated (Exs. 11 and 15), and went out, but very soon the vapor rose

fast enough to support a constant flame. See also Experiment 28.

It was not easy to blow out this flame, but a piece of paper laid over the cup extinguished it immediately.

How to put out a fire. If a person's clothing catches fire we extinguish it most easily by wrapping something around them. For more on this subject refer to Chapter III.

General Conclusions in Regard to Kerosene.—1. There are no solid products to be considered in the combustion of kerosene. They have been left behind in the process of refining the oil.

Solid products wanting.

2. Kerosene is a liquid at ordinary temperatures just as a candle is a liquid at higher temperatures. The liquid is carried up a wick by the same method in both cases.

Liquid at ordinary temperatures.

3. As the heat of a candle flame converts the melted candle to a vapor to feed its own flame, so the kerosene flame converts the liquid oil to a vapor to feed its flame.

Gaseous products at higher temperatures.

Note.—Each State has fixed, by law, a degree of heat below which kerosene must not give off vapor sufficient to support a flame: this is called the "flashing" point. In preparing it for market it is kept at the required temperature until all the products which will vaporize at that temperature have passed off.

"Flashing-point" of kerosene fixed by law.

4. We found that alcohol, ether, and many other liquids vaporized sufficiently at ordinary temperatures to support a flame upon their surfaces.

We found that camphor gum, sulphur, and such solids as burn readily with a flame were easily vaporized by heat.

We found that carbon did not under ordinary conditions burn with a flame, and we were unable to vaporize it.

Liquids and solids which readily support a flame vaporize rapidly at ordinary temperatures.

We therefore Conclude from all the Foregoing Experiments:—1. That liquids must be changed to gaseous form before they can burn. 2. That solids must be changed to gaseous form before they can burn with *flames*, but they may burn *without flame* in the solid condition.

Only substances in the gaseous state burn with flames.

Chapter XX.

KINDLING TEMPERATURE.

In the experiments where we heated paper, wood, and tallow in a tin box we noticed that the vapor would at times spring into a flame of its own accord. This suggested the idea of comparing different substances with reference to the temperature at which they take fire.

Phosphorus lighted by the heat of friction.

Experiment 36. We rubbed a piece of iron on a piece of wood, and the iron soon became so warm that when we touched it to phosphrous the latter sprang into flame.

Carbon bisulphide vapor lighted with a rod heated slightly.

Experiment 37. We put a few drops of carbon bisulphide into a tumbler. From its strong odor one would judge that it gives off a large quantity of vapor. We tried to light this vapor with an iron heated by friction. After convincing ourselves that it had a higher kindling temperature than the phosphorus, we warmed the iron slightly in the flame and, upon bringing it into the tumbler the vapor sprang into a pale-blue flame.

Certain things lighted by a red-hot wire.

We performed a similar experiment with ether, and found that the iron had to be heated somewhat hotter in this case, showing that ether vapor has a higher kindling temperature than carbon-bisulphide vapor. Attempts to ignite camphor gum, the vapor of turpentine, of heated kerosene, of alcohol, of gasolene, of heated

wood, and of heated paper with a red-hot iron wire proved unsuccessful; but the heat of the red-hot iron wire was found to be sufficient to ignite sulphur, the illuminating gas, and the gas obtained from wood and paper, as represented in Fig. 5.

Lighting a coal fire.

Variations in kindling temperature are well illustrated in the lighting of a coal fire. First, in the case of the match: the phosphorus is lighted by the heat of friction, the burning phosphorus lights the sulphur, the sulphur lights the wood. When the wood of the match is on fire, we light the paper in the stove, the burning paper lights the wood, and the wood lights the coal.

A flame extinguished by wire gauze.

Experiment 38. We took a piece of wire-gauze, such as is used for milk strainers or fine sieves, and brought it down over a flame. The flame would not pass through the gauze, but continued to burn below.

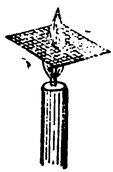
Fig. 14

When a lighted match was brought over the gauze a flame played above (Fig. 14), showing that a portion of the gas which supported the flame was passing through the gauze unburned.

A flame extinguished by "cheese cloth."

A similar experiment was performed with a loosely woven fabric, as "cheese-cloth." The flame of a laboratory burner was extinguished by bringing a single thickness of this cloth quickly down upon the end of the burner. After the flame had been extinguished it was lighted

again above the cloth by a match, and the cloth hastily removed before it took fire.

We concluded that the gauze had cooled it below its kindling temperature, and we waited to see what would happen if the wire-gauze should become heated above the kindling temperature of the gas, and found that when it became red hot it lighted the gas above it. This experiment was tried with the flame of illuminating gas, of an alcohol lamp, of a kerosene lamp, and of a candle, with similiar results.

In place of the wire-gauze we also tried, with success, some wire window-netting—holding it first in the flame to burn off the paint, and then folding it four double to make the meshes closer.

Experiment 39. We made something to represent a Davy's Safety Lamp, such as miners use, as follows: We

The miner's safety lamp. made a cylinder of wire-gauze, twisted wire around it to keep it from unrolling, fitted corks to the ends, and placed a lighted taper inside. We lowered this into a bottle * of illuminating gas (Fig. 15), without igniting the gas; but when a free flame was brought into the bottle the gas caught fire. In this experiment the bottle represents the mine, which has become full of a combustible gas.

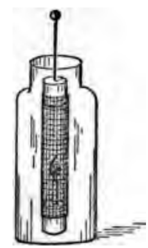

Fig. 15

* The method of filling the bottle with gas is as follows: Fill it first with water, and lay a piece of paper over its mouth; and while holding this on with the hand invert the bottle and bring

The miner's word for gas is "damp," and when he finds a gas that will burn he calls it "fire-damp." If he brings a free flame into this he fires the mine, but if he imprisons his flame in wire-gauze, as is done by the Davy's Safety Lamp, he may go into "fire-damp" without inflaming the mine; but the gas entering the lamp will affect the flame so as to warn him to leave.

In Experiment 38 we have a suggestion of a better way for performing Experiment 31. Bring a piece of wire-gauze into the candle flame, and hold the tube above it, as represented in Fig. 17. Smoke may be conducted up the tube so as to support a good-sized flame at *a*.

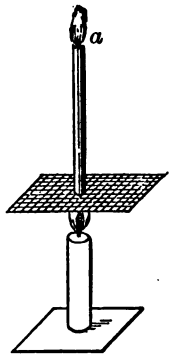

Fig. 17

Experiment 40. We placed the candle where a draft

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its mouth under a little water in a basin (Fig. 16). The paper may then be removed, and the bottle will remain full of water by atmospheric pressure. A piece of rubber tubing may be pushed over the "lava" tip of the gas pipe, and the other end of it brought under the mouth of the bottle by tipping it a little to one side, taking care not to raise it out of the water. When the stop-cock is turned the pressure on the gas in the pipe will cause it to flow unless the water in the basin is too deep. To make an explosive mixture of air and gas, see note on Experiment 55.

How to fill a bottle with gas.

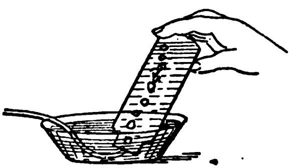


Fig. 16

Draughts of cool air cause flames to smoke.

of cool air blew upon it and noticed that it caused it to smoke. We wafted air toward it with the hand or with a fan. We carried it about, and in all these circumstances, when a cool supply of air came in contact with the flame a little more rapidly than usual, it produced a little smoke.

Cool objects brought into a flame cause it to smoke.

Experiment 41. We brought cool objects into the flame —a porcelain dish, a piece of glass, even a piece of writing-paper, which was withdrawn before it began to char. A little smoke was deposited upon all of them. From this experiment it seems evident that the black substance which we call soot, or carbon, is passing up through the flame in some volatile, invisible form, and by lowering the temperature a little we arrest it before it is completely burned up.

Smoke deposited upon a cool object disappeared when the object was heated.

Experiment 42. We held a piece of glass tubing in the candle flame until a considerable quantity of carbon had gathered upon it; we then brought the glass tube into an alcohol flame, and heated it until the carbon all disappeared.

Note.—Pure carbon requires to be heated to a high degree before it will burn. The heat of burning-paper gas is not sufficient to burn up the carbon of paper; hence when we burn paper we have the charred remains left, unless we heat to a higher degree, as we did in the tin box (Ex. 11). For the same reason we have a charred mass left when a match burns.

Experiment 43. We lighted the vapor of carbon bisul-

phide and brought a cold object into it, and found that sulphur was deposited. The "smoke" of this flame appears to be sulphur instead of carbon, although both are passing up through the flame in volatile form, and in spite of the fact that the kindling temperature of sulphur is very much lower than that of carbon. The observation is a valuable one, although the explanation of the phenomenon may not be pertinent to the present discussion.

Sulphur deposited from a carbon bisulphide flame.

The above experiment is analogous to Marsh's test for arsenic where a gas compounded of hydrogen and arsenic is burned, and when a cold object is brought into the flame arsenic is deposited.

Marsh's test.

Experiment 44. We tried burning a little sliver of pitch-pine, a little piece of camphor-gum, a piece of paper dipped in turpentine, etc. It would appear from such experiments that some fuels require a higher temperature than others for their complete combustion. This may suggest a convenient method of securing carbon in a finely divided condition, called "Lamp-black."

Experiment 45. Hold a tin box or glass bottle over the turpentine flame so as to collect a considerable quantity of "lamp-black." With this a great many interesting experiments could be performed; but they do not belong to the argument which we are pursuing at present.

Making "lamp-black."

Observation.—It is sometimes noticed that gas-lights in a cold room burn more dimly than they do afterwards when the room becomes warm.

Chapter XXX.

AIR AS AN AGENT IN COMBUSTION.

It would appear from the experiments with a candle (Experiments 29, 30, and 31) that the combustible vapor burns only at the outer edges, where it comes in contact with the air. The foot-note of Experiment 11 suggests that air is necessary for the combustion of paper smoke. Experiment 1 would indicate that the smoke formed inside of the "lamp-lighter" could not burn until it came in contact with the air, while the smoke that was formed on the outside of the "lamp-lighter" did burn because of the air.

Effect of excluding air from a flame.

Experiment 46. We brought a bottle down over the flame, as in Fig. 18, so that the flame was limited to the air which was contained in the bottle. It struggled a moment and went out.

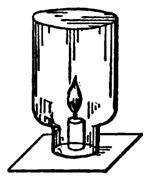


Fig. 18

Experiment 47. We lighted the candle again and brought the bottle over it as before. But this time, just as it was about to flicker out, we lifted the bottle, exposing the flame to the outside air, and it revived.

Experiment 48. We brought a lamp chimney over the burning candle, and placed a piece of paper over the top of the chimney; the flame went out. We relighted the candle and held the chimney over it, leaving a space for the air to enter below.

As we brought a piece of paper over the top the flame began to die out; when we lifted the paper again it revived.

Query.—Why do some factory chimneys have dampers at the top? Why do we have a damper in the stove-pipe?

Dampers in chimneys and stove-pipes.

Experiment 49. We brought the chimney down over the candle, and let it rest upon the card-board base so as to prevent air from entering at the bottom, leaving it open at the top. The flame went out, but not so promptly as before.

Queries.—Why do we close the "draught" of the stove when we wish to check the fire? Why do we blow the fire when we wish to make it burn better? Does it not tend to cool the fuel below its kindling temperature?

Stove "draughts."

Experiment 50. We brought the chimney over the flame, leaving it open above and below. When "lamplighter" smoke was brought to the bottom it was drawn in and carried up the chimney. When tissue-paper was brought to the top it was wafted upward. Evidently there was a current of air drawing up through the chimney.

Experiment 51. We rolled paper into a large tube for

a chimney and cut a hole in the side, then brought this down over the candle, nearly closing the aperture at the bottom. When "lamp-lighter" smoke was brought to the hole at the side it was drawn in and carried up the chimney.

Queries.—Why do we have ventilators opening into the chimney-flue?

Ventilators.

Laboratory burners.

Why do laboratory lamps have holes at the bottom?

Experiment 52. We brought the phosphorus end of a match quickly into the interior of the candle flame. The phosphorus melted, but did not burn until it came in contact with the air.

No combustion in the dark center of the flame.

Experiment 53. We thrust a lighted splinter into some alcohol. The alcohol burned quietly at the surface, but it extinguished the flame from the splinter which was dipped into it.

No combustion below the surface of the alcohol.

The flame of the alcohol was extinguished by laying a piece of paper over it. This suggests that the most effective way to put out a flame is to smother it, that is, to keep the air away from it.

Another way would be to cool the flame below its kindling temperature.

Extinguishing fire with water.

Query.—Why do we throw on water to extinguish a fire?

Experiment 54. We filled a bottle with illuminating gas and plunged a lighted splinter into it. The gas burned at the mouth of the bottle, but it extinguished

the flame from the splinter. A similar experiment was performed with hydrogen gas, and with the gas collected from paper, from wood, and from tallow, as represented in Fig. 5.

Extinguishing fire with a combustible gas.

Experiment 55. We filled a bottle with a mixture of air and illuminating gas (about five-sixths air). When a flame was brought to the bottle it flashed through the whole mass, burning it all at once.

Note.—The gas is to be passed into the bottle as described in the foot-note to Experiment 39. After the bottle is about one sixth full of gas, allow air to pass in, a little at a time, by raising the mouth slightly from the water.

We tied rubber-cloth over one end of a lamp-chimney and then filled it with a mixture of gas and air.

When we exploded it the rubber-cloth was thrown into rapid vibrations from which we reasoned that there had been a sudden expansion followed by a sudden contraction. This suggests what sometimes happens in a mine.

Explosions.

Experiment 56. We took a tube with an opening in the end as small as a pinhole and forced a stream of air through it into the dark center of the candle flame. The flame was made sufficiently hot to melt glass readily. This is called a blowpipe.

The blowpipe.

Query.—Why do certain forms of kerosene lamps have a tube extending up inside of the flame?

Lamps with central tube.

Conclusions with Regard to Air as an Agent in Combustion.—The air is essential to combustion.

The first effect of decreasing the supply of air in every case is to cause a flame to smoke a little; that is, the process of combustion is arrested in part and some carbon is deposited unburned.

If the supply of air is too great the effect is to cool the fuel below its kindling temperature. The best results are obtained by a blow-pipe or bellows so arranged as to carry a stream of *hot* air to the burning fuel.

When air is thoroughly mixed with a combustible, burning may go on throughout the whole mass at once; (If this is sufficiently sudden it is called an explosion), but otherwise the combustible will burn only in those portions of the mass which are in contact with the air.

Burning a jet of air in a bottle of coal-gas.

Since combustion takes place where the combustible gas comes in contact with air it follows that if air were conducted through a gas-pipe into an atmosphere of any combustible gas it would burn at the tip of the pipe as represented in the accompanying figure (Fig. 19). We performed the experiment by conducting air through a tube from the bellows and burning it in a bottle of coal-gas.

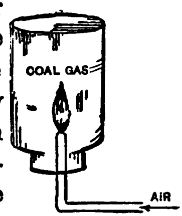


Fig. 19

If air is wholly excluded, combustion is impossible, but the combustible if heated sufficiently without air may be decomposed chemically into other constituents.

Queries.—What is a combustible? A supporter of combustion? How is noise caused by an explosion?

A Reflection.—In making a definition in natural science we attempt merely to sum up our present knowledge, and not to comprehend all possible cases. For example, we may not say that an animal with a backbone *must* have two eyes; but we do say that vertebrates, *so far as we know,* have two eyes.

Making definitions.

There are many queries which no one can positively answer. We should learn to weigh the arguments for or against a theory but we should learn to train our minds to hold open court continually for further evidence.

Premature conclusions.

Chapter XV.

PRODUCTS OF COMPLETE COMBUSTION.

THUS far we have been noting some of the phenomena which may attend combustion, but we have paid no attention to the *final* products.

When the paper, or the wood, or the candle, burn freely in the air the greater part of them disappears.

The following experiments will show very plainly that the products which we have obtained thus far are, for the most part, intermediate substances, obtained only when the natural process of combustion is arrested.

Smoke is only an intermediate product of combustion.

The same may be said of the charred paper of the "lamp-lighter," or the charcoal in the case of the wood.

The vapor products, liquid products, and solid products, except the ashes, are all merely *partly* burned material which have failed to disappear utterly, only because there was either an insufficient supply of air, as in case of the vapor formed in the inside of the "lamp-lighter" (Experiment 1), and in case of the vapor of the wood in the tin box (Experiment 15), or because the temperature is not sufficiently high to carry the combustion to its completeness, as in case of the charred paper of the "lamp-lighter."

A few simple experiments will enable us to trace those substances on through complete combustion and find

that although they cease to be visible they still exist, just as the air is invisible and yet exists in tangible form when, for instance, it takes on the speed of the hurricane, unroofing houses and uprooting trees.

Making lime-water.

Experiment 57. We prepared some lime-water by putting a little unslaked lime into water, stirring and allowing it to settle, then pouring off the clear liquid. This liquid has a little lime dissolved in it and is therefore called lime-water. It is used for a specific purpose as we shall see in the next experiment.

Catching a gas by "upward displacement."

Experiment 58. We put some pieces of charcoal into a tin box and heated them over a flame. They glowed at the tips and slowly wasted away. We held a bottle inverted * over this burning charcoal and in a few minutes we held a piece of paper over its mouth and turned it right side up. Then we poured into it about a tablespoonful of lime-water and gave it a good shaking. The lime-water turned milky.

A gas which turns lime-water milky.

Experiment 59. We washed out the bottle and put lime-water into it while it contained nothing else but the air in the room, and upon shaking it the lime-water did not become milky. We had collected something from the burning charcoal which had the property of turning lime-water milky.

* Although the gas formed is heavier than air at the ordinary temperature, it is light enough at the temperature of burning charcoal to be caught by "upward displacement."

Experiment 60. We brought a lighted splinter into the box over the glowing charcoal of Experiment 58, and the flame was immediately extinguished. We inverted a bottle over the tin box and after a time, placing a piece of paper over its mouth, we put it right side up on the table, and when a lighted splinter was brought into the bottle it went out as before.

The gas extinguishes a flame.

We filled the bottle with water so as to drive out whatever gas might be in it, and then emptied out the water so as to get air into it. We then brought a lighted splinter, for a moment, into the bottle of air and it was not extinguished.

We had collected from the burning charcoal something which had the property of extinguishing a flame.

Many kinds of fire extinguishers contain the necessary substances to generate this gas, and when they are broken the burning fuel is enveloped in such a large quantity of the gas as to extinguish the flame.

Fire extinguishers.

We tried similar experiments with various burning substances—flames of a candle, of alcohol, of gas, of kerosene, etc.—and obtained from all of them an invisible gas which had the properties of extinguishing a flame and of turning lime-water milky.

Now if no other gas will turn lime-water milky except that which is the product of burning carbon, (and so far as men have experimented this has proved to be true) it then follows that lime-water may be used as a test for the presence of this gas.

Lime-water a specific test for this gas.

Note to Teachers.—It does not add very much to the pupils' education to learn the *name* of this gas. It will be a mere matter of convenience to have some name for it, and the better that name describes its properties, as they understand them, the better it will answer the purpose.

The significance of a name.

Perhaps the name which chemists give it is not the best name for beginners, inasmuch as it describes properties which they know nothing about and hence the name will have no significance to them. At present they will more naturally call it "The gas which turns lime-water milky." When their knowledge has increased farther we shall be able to evolve from experimental knowledge a shorter and a better name which, when they have learned enough about the substance to be ready for it, will neither be difficult to understand nor hard to remember.

Merely learning the names without a knowledge of the things themselves appears to be a widespread fault.

Experiment 61. We collected some vapor from a "lamp-lighter" which we found from Experiment 10 to contain carbon. We set fire to the vapor, and after the flame went out laid a piece of paper over the mouth of the bottle.

When lime-water was put into the bottle and shaken, it turned milky.

Note.—This experiment suggests what happens when a coal mine explodes. The bottle filled with the mixture of air and vapor represents the coal mine filled with a mixture of air and a combustible gas called "fire-damp." When

"Fire-damp" and "choke-damp."

a flame comes in contact with this an explosion occurs in which the "fire-damp" is burned up; and the miners say that immediately after an explosion the mine is filled with "choke-damp" (choke-gas), which is nothing else than "the gas which turns lime-water milky."

We learn, therefore from the experience of the miners that this gas produces a choking sensation.

It turns lime-water milky. It extinguishes a flame. It chokes animal life.

The gas chokes, rather than poisons, animal life.

It seems probable that it is not a distinct poison; but that it can only cause death when breathed in large quantities enough to prevent the person from getting a sufficient quantity of air, just as a person dies from drowning or smothering. It extinguishes a flame for the same reason.

The flame of the splinter in Experiment 60 was extinguished for the same reason as the flame of the candle in Experiment 46, namely, for the want of air.

Experiment 62. We collected in a bottle some gas formed from wood, as represented in Fig. 5, and after burning it we tested the contents of the bottle with lime-water. It turned milky, proving that that gas contains carbon.

Testing for carbon in organic substances.

By applying heat to anything which has had life, either plant or animal, or to those things which are produced by living things, such as tallow, wood, paper, sugar, starch, etc., we may either char them and thus form carbon directly, or we may burn them and form the gas which turns lime-water milky, proving the presence of carbon.

We thus reach the conclusion that when anything containing carbon is burned, the carbon goes off in an invisible gas which is detected by its property of turning lime-water milky.

This gas rises unseen, above every flame and goes off into the atmosphere. We shall learn from future experiments that it is composed of carbon united with one of the constituents of the air.

The products of combustion equal the fuel plus the portion of the air consumed.

When a ton of hard-coal is burned, its carbon unites with about two and two-thirds tons of the element which it takes from the air forming about three and two-thirds tons of "the gas which turns lime-water milky."

Thus when the paper, wood, candle or any fuel is burned up, matter is neither destroyed nor diminished in weight, but only changed in form.

This first product of complete combustion we shall often meet in our study of chemistry, physiology and botany.

We shall hereafter learn other important properties of it which will furnish occasion for a new name. At present we call it "The gas which turns lime-water milky."

Another product of combustion is water.

Experiment 63. We filled a bottle with water, taking care that the outside was perfectly dry, and held it about six inches above the flame of the alcohol lamp. Considerable water gathered on the outside of the bottle and trickled down the side, as steam condenses on the window-pane on "washing day."

Experiment 64. We emptied out the water from the bottle and carefully wiped it dry, inside and outside. When it was brought over the flame it gathered moisture again. The bottle warmed faster now than before when it contained water, and as we continued holding it there the moisture disappeared; but whenever any cold thing was brought over the flame, we noticed that it had a tendency to gather moisture, and the colder the object the more moisture would be collected.

Experiment 65. We lighted a kerosene lamp and when a cold chimney was put on it, we noticed a little moisture gathered on the inside but gradually disappeared as the chimney became heated.

Fig. 20

Experiment 66. We held, with paper-holders, two argand lamp chimneys over the flame of an alcohol lamp, as represented in Fig. 20, directing the upper end against the window-pane. A considerable quantity of steam collected on the window-pane and trickled down in drops.

There seemed to be a strong upward current through

the chimneys which directed the flame side-wise. This will be referred to again in Chapter V.

Similar experiments, with various kinds of flames, revealed the fact that water is formed in them all and arises above them in the form of an invisible vapor or steam.

It was noticeable, however, that a much larger quantity of water is formed from some flames than others.

An alcohol flame yields a very abundant quantity of water and a comparatively small amount of carbon while a tallow candle yields large quantities of carbon and less water vapor.

We conclude:

Composition of fuels and organic substances in general.

1. That fuels, in general, contain *carbon* and something else which, when burned in air, forms *water*.

2. That most things which have been intimately connected with the life process form, when burned, the same products as ordinary fuels do.

Cremation.

3. That matter is not annihilated when it is burned but only changed in form. Dead bodies and offal when cremated are changed to harmless substances as water-vapor, and "the gas which turns lime-water milky."

Chapter V.

CURRENTS IN THE AIR WHICH CARRY AWAY THE PRODUCTS OF COMBUSTION—VENTILATION.

EXPERIMENTS 50, 51, and 66 show that there is an upward current of air through a chimney when a flame is placed inside of it. Two important results are accomplished by this. First, a constant supply of fresh air is brought to the flame to assist combustion. And second, the products of combustion are carried away from the flame so as not to interfere with its burning.

Blast furnaces.

In a measure, every furnace is a blast furnace, but when more vigorous combustion is desired, a stronger blast is produced by mechanical devices.

Ordinarily, the flame of the candle points upward, in whatever position the candle may be held; but not so if, by any means, we are able to change the direction of the currents of the air. If the currents blow sidewise, the flame points sidewise; if downward, the flame points downward. Recall experiments 66 and 56.

By means of the blow-pipe the flame may be made to take any direction desired. The same thing may be accomplished by moving the flame rapidly through the air.

Experiment 67. We investigated with "lamp-lighter" smoke and with tissue paper, the currents of air in the

vicinity of an uncovered flame. There was found to be a slight movement of air from all sides toward the flame and a strong upward current over the flame.

The burning candle may be used to illustrate storm centers. Currents of air move from all sides toward the storm and at the center there is an upward current. By this means, air laden with moisture is carried up into the cold regions above and the moisture is deposited as rain, just as the moisture which was carried up the chimney in experiment 66 was deposited as water upon being cooled.

Storm centres.

After the air, which has been carried up in a storm, becomes cold and dry it comes down again at some distance, and there we have particularly fine weather. And in that region the barometer indicates that the air is heavier than usual, while at the storm center the barometer stands low, showing that the air is lighter than usual.

These are technically called "areas of high pressure" and "areas of low pressure."

Experiment 68. We cut holes in the cover of a pasteboard box, or cigar-box, and having placed a lighted candle in one of them as represented in FIG. 21, we covered them both with lamp-chimneys (*a*) and (*b*).

When paper-smoke was brought to the top of chimney (*b*) there was found to be a strong *downward* current. The smoke was carried along through the box and up chimney (*a*).

Chimney (*a*) represents an "area of low pressure," and chimney (*b*) an "area of high pressure."

By this means an underground cavern might be ven-

tilated. Let the box represent a coal mine, and the two

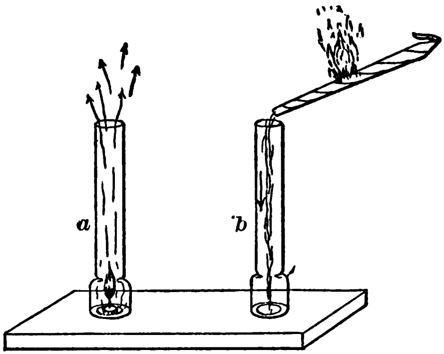


Fig. 21

Ventilation. lamp-chimneys, shafts leading from the surface of the earth down to the mine. If a fire is built in one of them, it will cause fresh air to be carried down the other and circulate through the mine.

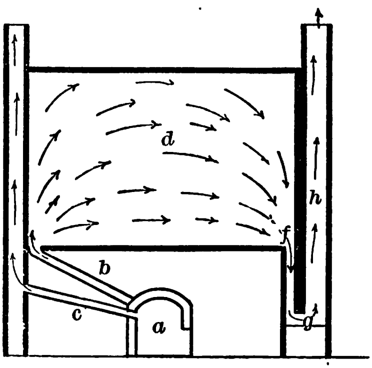


Fig. 22

A building may be ventilated by a similar plan as represented in Fig. 22.

The position of a furnace is represented at (*a*). Hot air is carried by the pipe (*b*), and smoke by the pipe (*c*). The hot air rises to the top of the room (*d*). The air is drawn out at (*f*)

and carried up the flue (*h*) by some source of heat, as an oil-stove, at (*g*).

We represent the same thing in a more concise form by the following experiment.

Experiment 69. We placed a common lamp-chimney over a lighted candle (fig. 23), so that no air could enter at the bottom. We cut from sheet-tin a piece such as is represented (*a*), and suspended this inside the chimney. When paper smoke was brought to the top of the chimney, it was found that there were downward currents on one side of this partition and upward currents on the other.

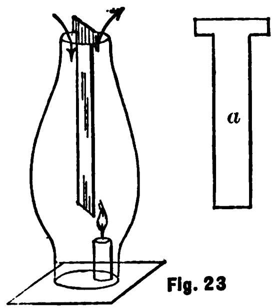


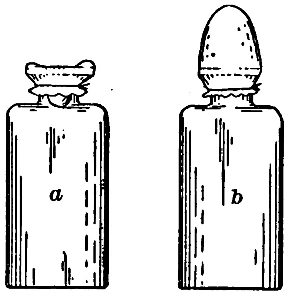
Fig. 23

Thus, the chimney being well ventilated inside, the flame burned all right. Fresh air was carried into the flame on the left side of the partition, and the products of combustion were carried out on the right side of the partition.

When the top of the chimney was covered at the left of the partition, the flame went out for the want of fresh air. When the top of the chimney was covered at the right of the partition, the flame went out, being choked by the products of combustion.

Experiment 70. We tied a rubber tissue bag over the mouth of a bottle, as in Fig. 24 (*a*), arranging it so that it sagged down inside, but taking care to fasten it perfectly air-tight.

The rubber balloon from a child's "penny whistle" may be used for the tissue bag.



a *b*

Fig. 24

While holding the bottle the heat of the hands caused the air inside to expand, as was shown by the rubber tissue. But when the bottle was slightly warmed over a flame the expansion of air inside stretched the bag to its utmost capacity, as represented at (*b*).

Expansion of air by heat.

Experiment 71. We inverted a bottle in a dish and poured in enough water to seal the mouth. We clasped both hands around the bottle, holding them there several minutes. Bubbles of air constantly escaped from the bottle through the water.

Experiment 72. We heated the bottle over the flame and held its mouth under water while it cooled. The water rose until it filled the bottle more than a quarter full.

This suggests what may be seen any time in the kitchen when tumblers are washed. When they are brought out of hot water and inverted on the table, the cold air which is inclosed by them becomes heated and expands. It may be seen bubbling out through the water which drains down from the sides of the tumbler upon the table, and seals the mouth.

After the tumbler begins to cool, the air may be seen bubbling in again through the water.

The air thermometer.

This also suggests the air thermometer, which may be understood by the accompanying Fig. 25. It consists of a tube with a bulb on the upper end. A scale is appended to the tube, and the lower end dips into a liquid. The bulb is warmed, and air bubbles out through the liquid. When it cools, the liquid rises up the tube. Slight variations in temperature cause the air in the bulb to expand or contract, and the movements of the liquid in the tube can be noted from the scale just behind it.

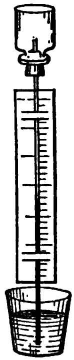


Fig. 25

How heating air causes currents.

By referring to Fig. 21 we shall now be able to explain the cause of the currents of air. The candle flame heats the air in chimney *a*, causing it to expand, and some of it is thus driven out of the chimney. Chimney *b* now contains more air than chimney *a*, and presses down more heavily on the air in the box, pushing some of it up into chimney *a*.

This is the explanation of the currents of air in the ventilation of buildings; of the currents of air in our atmosphere which we call winds; of the currents of water in a vessel where one portion is heated more than another; and of ocean currents.

Query.—Why are factory chimneys made so tall?

Experiment 73. To show that the air has weight, we

tied rubber-tissue over the large end of an argand lamp-chimney, taking care that it should be air-tight (Fig. 26). We filled this with water, and holding a piece of paper over the top, we inverted it, bringing the small end into a little water, and then removed the paper. As the water attempted to recede from underneath the rubber-tissue, the weight of the air above stretched it downward with considerable force.

Air has weight.

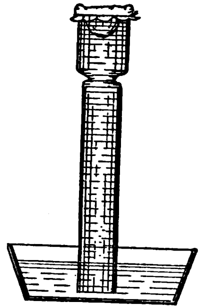


Fig. 26

Its weight compared with that of a barrel of flour.

In a room sixteen feet long, fifteen feet wide, and ten feet high the air weighs about as much as a barrel of flour.

Chapter VI.

THE OXYGEN OF THE AIR.

Experiment 74. We put a piece of crumpled paper on a plate, and having set fire to it we inverted a tumbler over it and poured water into the plate to seal the mouth of the tumbler.

After the blaze was extinguished from the paper the water rose rapidly in the tumbler.

This experiment is sometimes performed to show that a part of the air is burned up. It is however, not a satisfactory proof of this statement: first, because considerable of the air in the tumbler was expanded by the heat of the burning paper and driven out. Water rose in the tumbler, when it cooled for the same reason as in Experiment 72; and, second, because the gas formed by the burning paper occupies as much space as the portion of the air consumed.

The following experiment gave more satisfactory results:

Experiment 75. We dropped a little piece of clean phosphorus * into a test-tube and crowded a small piece

* Phosphorus is not expensive, and can be obtained without difficulty. It should be kept and cut under water, because it is liable to take fire. In the above experiment the piece was no larger than a pea, and it was thoroughly scraped to render the surface fresh and clean.

of wire-gauze about half way down the tube, then inverted it in a tumbler containing a little water (Fig. 27).

Fig. 27

The phosphorus rested upon the wire-gauze. After a day or two, it was found that the water had risen in the test-tube. We poured water into the tumbler so that it stood at the same level outside and inside the tube.

Oxygen constitutes one fifth of the air.

The depth of the water was found to be one and one-fifth inches, and the length of the test-tube was six inches, showing that about one fifth of the air in the tube had been removed.

Placing the thumb tightly over the mouth of the test-tube while it was under the water, we raised it, and turning it mouth upward, tested it with a glowing piece of charcoal.

The fire was immediately extinguished from the charcoal when it was brought into the mouth of the test-tube.

Evidently that portion of the air which the phosphorus had removed is the part which supports combustion. This has been arbitrarily named oxygen. That which remained in the test-tube is called nitrogen.

When the clean phosphorus was introduced into the tube white fumes were formed, which eventually disappeared, and the water in the tumbler showed slight acid properties at the close of the experiment.

Experiment 76. We put about a tablespoonful of

chlorate of potash into a small spice-box and heated it over a flame. It soon melted, and appeared to boil. We brought a lighted splinter into the mouth of the box, and it burned very brilliantly. We brought a piece of glowing charcoal into the mouth of the box, and it burned rapidly.

Making a gas from chlorate of potash.

We held a bottle inverted over the burning charcoal, and afterwards tested its contents with lime-water, and the lime-water turned milky.

If we mix black oxide of manganese with the chlorate of potash, the gas will flow more gradually, and will require less heat to produce it.

Experiment 77. We arranged an apparatus as represented in Fig. 28, filling the test-tube about

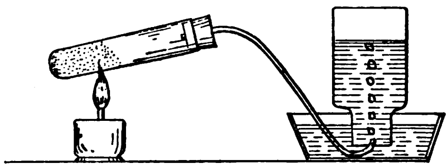


Fig. 28

one-third full of a mixture of equal parts of chlorate of potash and black-oxide of manganese, and heated it in the flame, taking care not to melt the rubber stopper in the test-tube, and moving the flame to and fro so as not to heat the test-tube all in one place.

Collecting the gas over water.

With this arrangement we collected several half-pint bottles full of the gas, and covered them with wet paper.

Experiment 78. With a penknife we dug out a cup in the large end of a piece of blackboard crayon about one inch long, and attached a wire as represented in Fig. 29. This serves the purpose of a "combustion-spoon."

A "combustion spoon."

Fig. 29

Experiment 79. We poured a little lime-water into a bottle of the gas formed in Experiment 77, and shook it well. It did not turn milky.

Carbon burned in the gas.

We laid a short piece of charcoal across our "combustion-spoon," and held it in the flame until it began to glow, and then brought it into the bottle of gas. It burned brilliantly. We then shook up the bottle of lime-water, and it turned milky.

It appears that this gas is the same as that portion of the air which supports combustion, namely, oxygen.

We note that things would burn much more brilliantly if our atmosphere were composed entirely of oxygen.

Since the gas which turns lime-water milky is composed of carbon and oxygen, it might be appropriately called *carbonic oxide*.

Experiment 80. We put a little sulphur into our "combustion spoon" and lighted it in a flame.

Sulphur burned in the gas.

The gas which arose from the burning sulphur had the familiar odor of a burning sulphur match. When it was brought into a bottle of the gas formed in Experiment 77 the sulphur

burned with a beautiful blue flame, and the bottle was filled with fumes which had the same odor as those arising from sulphur when burning in the air. This is additional proof that the gas is the same as that portion of the air which supports combustion.

These fumes of burning sulphur turned wet litmus-paper red, thereby showing that they had acid properties.

Experiment 81. We put a small piece of phosphorus into our "combustion-spoon" and lighted it. The white fumes which were noted in Experiment 75 were formed abundantly while it burned in the air, but much more abundantly when it was brought into a bottle of the gas formed in Experiment 77, where the phosphorus burned with great brilliancy. The fumes turned wet litmus-paper red, showing acid properties.

Phosphorus burned in the gas.

We have in this experiment additional proof that the gas formed from chlorate of potash is the same as the oxygen of the air.

Experiment 82. We took a broken watch-spring (which the jeweller seemed glad to give away), and, having straightened it by drawing it between the thumb and finger, we tied a little piece of string around one end of it, and dipped this in melted sulphur. We then lighted it, and brought it into a jar of the oxygen. The sulphur soon burned up but in so doing it set fire to the watch-spring which burned, in a startling manner.

A watch-spring burned in the gas.

We took precaution to have a little water in the bot-

tom of the bottle during this experiment to prevent bits of burning steel from cracking the glass.

What causes iron to rust.

At the close of the experiment the sides of the bottle were well covered with a brown substance which looked like iron rust.

This suggests that it is the oxygen of the air which causes iron to rust.

Carbonic oxide from the lungs.

Experiment 83. We put some lime-water into a bottle, and having breathed into it a few times we shook it up and it turned milky.

It would appear that we breathe in air containing oxygen and breathe out carbonic oxide.

Is there something analogous to combustion which is going on inside the body?

Carbon in animal matter.

Experiment 84. We took some animal matter,—bone or cartilage, lean or fat meat, hair or nails—and heated them. They charred, indicating the presence of carbon, and when we burned them, carbonic oxide was formed, as was shown by the lime-water test.

Experiment 85. We made some hydrogen gas and burned * it. When a cold dry bottle was brought over the flame, water was deposited upon it.

* Those who are not familiar with hydrogen are advised to study the chapter on that element in some chemistry where all the necessary directions for the manipulation of the experiment will be found.

This seems to indicate that water is composed of hydrogen and oxygen, which is found to be a fact by experiments more extended than we can pursue at present.

Water composed of hydrogen and oxygen.

The fact that we obtained water as one of the products of the complete combustion or oxidation of various fuels, seems to indicate that hydrogen is one of their constituents.

Hydrogen in fuels.

The large quantity of water which is eliminated from the body by means of the lungs, skin, and kidneys, shows that hydrogen is an important element in it.

Hydrogen in the body.

Is any of the water which leaves the body due to the oxidation of hydrogen by a process analogous to combustion?

Conclusion.—One-fifth of the air is oxygen.

This oxygen *unites* with fuels in the process which we call combustion, forming with their carbon, carbonic oxide, and with their hydrogen, water.

In the process of respiration, it may be supposed that the oxygen of the air unites with the carbon of the body to form carbonic oxide, and with the hydrogen of the body to form water. Although one may not determine positively about the chemical changes which go on inside of a living body, it is probable that these results are brought about by a long series of chemical changes which are more nearly akin to the processes of fermentation and decay. The processes of fermentation and decay of organic matter result in the formation of carbonic oxide and water.

Carbonic oxide and water formed by fermentation and decay.

Oxygen rusts metals and unites with many other classes of substances, forming compounds which are called oxides.

Nearly all the remaining four-fifths of the air is a gas called nitrogen.

Nitrogen in the air.

Queries.—Is nitrogen poisonous?

Why does it put out a flame?

Would it extinguish life for the same reason?

If carbonic oxide contains the oxygen which it obtained from the air, why does it extinguish a flame while air supports a flame?

For an answer to this query look in some chemistry for the distinction between a chemical compound and a mechanical mixture.

If carbonic oxide is a product of animal respiration, of combustion of fermentation, and of decay, is our atmosphere becoming surcharged with it?

Look in some botany to see what the vegetable kingdom does with carbonic oxide.

Chapter VII.

CHEMICAL CHANGES.

THE study of the natural and physical sciences depend so much upon the knowledge of chemical changes that it seems appropriate to close this *Introduction to the Study of Science* with a chapter on *chemical changes.*

All living things whether animal or vegetable, devote a large part of their energy to the process of taking food; which, in short, is the process of taking outside substance into the body, putting them through chemical changes, and making them a part of the body.

Living things composed chiefly of four elements: carbon, nitrogen, hydrogen, and oxygen.

A knowledge of chemical changes, therefore, will help us to understand the process of making flesh and blood.

Animals and plants are made up, for the most part, of *four* elementary substances, one solid and three gases.

The solid is *carbon.* The three gases are *nitrogen, hydrogen,* and *oxygen.* These four substances, combined in various ways, constitute living things.

It is a very familiar fact, that by heating animal or vegetable substances we may char them, i.e., heat expels

the gases present, and leaves behind the well-known black solid which we call *charcoal,* when it is obtained from vegetable substances; and, when it is obtained from animal substances, it is sometimes called *animal charcoal* to indicate its origin. Both, however, are one and the same thing—the all-important elements—*carbon.*

Carbon from sugar by heat.

Experiment 86. Put some sugar on a tin dish and set it on the top of the stove, or heat it over a flame. The other elements of the sugar are driven off and the charred mass which is left behind is carbon.

Taste it after it is thoroughly charred and notice that the sweetness is entirely gone. Try its solubility in water. Compare it with sugar in this respect.

Most fats decompose below their boiling point.

It was noticed in experiment 32, that when fats are heated they turn darker color as if some carbon was formed in them. This is true. Fats decompose as the sugar did in the above experiment before they reach the boiling point. When they appear to boil it is generally due to the water in them which is driven off as steam.

The same thing is noticed when a sugar solution is heated. It turns darker colored because of the small particles of carbon which come from the gradual decomposition of the sugar.

See also experiment 10.

Experiment 87. Take about a third of a tea-cupful of

boiling water, set this upon the stove or over a flame and stir into this, sugar enough to make a syrup so thick that a slight crust will form upon it when it cools. Now set the cup containing the syrup into an earthen or glass dish, it should be a dish of three or four quarts capacity, and pour strong sulphuric acid slowly into the syrup while stirring constantly. Very soon the sugar solution is changed to a black spongy mass which swells up and fills the tea-cup and perhaps a good part of the dish. See Fig. 30.

Carbon from sugar by sulphuric acid.

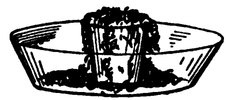


Fig. 30

In this case the sulphuric acid has taken the other elements of the sugar to itself and left the carbon in the form of this black spongy mass. Wash this several times by stirring it up with water and draining it off. Repeat this until the sour taste of the acid is removed. Compare the product with that obtained in the last experiment, as to taste and solubility.

The foregoing chapters furnish abundant evidence that organic substances contain carbon, which is the corner-stone of all living things; also, that organic things contain an admixture of mineral matter which we call ashes after the organic portion has been dissipated by heat.

How are we to understand that gases added to carbon may make all the varied forms of organic things?

A few experiments may help us on toward that conception.

Experiment 88. Put into the palm of the hand a little unslaked lime and a little sal-ammoniac. Rub them together with the thumb and fingers of the other hand. Ammonia gas will arise as the result of chemical action.

Two solids unite to form a gas.

Making ammonia.

In this case we have put two solids together and formed a gas.

In the next experiment we shall put two gases together and form a solid.

Every one knows that the odor of liquid ammonia is due to a gas which is escaping from it. Similarly, another kind of gas arises from a bottle containing strong liquid hydrochloric acid.

Now we may bring these two gases together by opening the mouths of the bottles containing the liquids near each other.

A more satisfactory way of trying the experiment will be the following:

Experiment 89. Put a few drops of ammonia water into a tumbler, or a wide-mouthed bottle, and a few drops of strong commercial hydrochloric acid into a similar vessel.

Two gases unite to form a solid.

The gases will rise and fill each of the vessels. Cover them both with pieces of paper to prevent the gases from escaping.

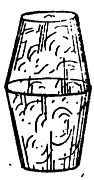


Fig. 31

Invert one vessel over the other, and slide out the pieces of paper from between them so as to allow the gases to come together. See fig. 31.

Immediately a dense cloud of small white

particles is formed, which, after a time, are deposited upon the bottom and sides of the vessels. Of course a very exceedingly small quantity of solid matter must be expected from so small a quantity of gases.

Making sal-ammoniac.

The substance which we have formed in this experiment is nothing else than *sal ammoniac,* such as was used in the last experiment, and such as is used in batteries for ringing electric bells.

If the process of mixing, in experiment 88, is continued for some time it will be noticed that the substances grow moist and tend to liquify. If the substances were sufficiently pure and taken in proper proportions, they would be completely liquified in time.

Two solids unite to form a liquid.

In the next experiment we shall suddenly convert two liquids into a solid.

Experiment 90. Put two or three tablespoonfuls of water into a tumbler and dissolve in it about the same bulk of calcium-chloride. Into this solution pour, slowly, strong sulphuric acid while stirring constantly. The whole will solidify and "set" in the tumbler so that it may be inverted without losing any of its contents. (See fig. 32.)

Two liquids unite to form a solid.

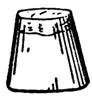


Fig. 32

Making "plaster of Paris."

It is "plaster of Paris."

Notice the odor of hydrochloric acid during the experiment.

Notice how heat is produced by the chemical action.

Query.—If oxygen uniting with the carbon and hydrogen of fuels produces heat; if lime uniting with water produces heat; if sulphuric acid uniting with sugar solution produces heat; and if sulphuric acid uniting with calcium-chloride produces heat, what do these facts signify?

Heat produced in chemical action other than combustion.

How temperature is affected in making solutions.

Notice also the change of temperature when sulphuric acid is put into water, also when the following is put into water:

Freezing mixtures.

A mixture of two parts ammonium nitrate and one of ammonium chloride, pulverized.

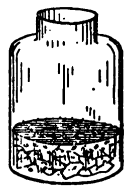
Examine the "plaster of Paris" formed in the above experiment, and see how unlike it is to either of the substances with which we started. Consider how very soluble the calcium chloride was. Try the solubility of this.

In the next experiment we put a solid and a liquid together to form a gas.

Experiment 91. Take some carpenter's chalk (blackboard crayon is not chalk, but is "plaster of Paris," such as was formed in the last experiment), put it into some dilute * hydrochloric acid in a bottle (Fig. 33). Gas is formed abundantly, which bubbles up through the liquid and fills the bottle above. Plunge a lighted splinter into

A solid and a liquid unite to form a gas.

Fig. 33



* About 10 parts of water to 1 of acid.

the mouth of the bottle. It is immediately extinguished.

Invert another bottle over this, and test its contents with lime-water. It turns milky, showing that carbonic oxide, with which we have already become familiar, is formed.

Carbonic oxide formed from chalk and acid.

Allow the process to go on as far as it will, and then pour out the liquid contents of the bottle into an open dish,—a saucer, for instance,—and warm until all the liquid has evaporated. Examine the solid which is left in the saucer. Notice how unlike it is to the chalk with which we started. Consider how insoluble chalk is; try the solubility of this. It is *calcium chloride,* such as was used in the last experiment.

We put chalk and hydrochloric acid together, and obtained from them as a result of the chemical changes carbonic oxide and calcium chloride.

Definite proportions.

Note.—If suitable proportions of chalk and acid could be taken there would be none of either left over at the close of the experiment. The bottle in that case would contain only calcium chloride and water.

If an excess of chalk is taken it will appear to dissolve until the acid is all used up, and then the action will cease. The bottle in this case will contain calcium chloride, water, and the chalk which remains. In like manner, if an excess of acid were taken the chalk would all disappear, and some acid would still remain in the solution of calcium chloride and water at the close of the experiment.

We may substitute, in place of chalk, marble, shells, or anything called a *carbonate*. Try putting acid upon wood ashes.

A gas and a liquid unite to form a solid.

If we allow the lime-water which has been turned milky by carbonic oxide to stand, a white powder will be found to settle at the bottom, and the liquid will become clear.

The white powder is *chalk*, and is produced by a chemical change between the lime-water and the carbonic oxide.

Making chalk.

If suitable proportions of lime-water and of carbonic oxide are used, none of either will remain, but they will be wholly converted into chalk and water.

The chalk and water looks milky or turbid—just as water would with finely powdered chalk stirred into it.

Chemical changes still more wonderful than all these are constantly going on in the body, and by them various food-stuffs are changed into body-tissue.

Chemical changes in the body.

A convenient way of expressing what happens in the case of such chemical changes as the above is by using equations somewhat as follows:

Chemical equations.

Calcium Chloride + Sulphuric Acid = "Plaster of Paris" + Hydrochloric Acid. (Some hydrochloric acid was formed in this experiment and was absorbed in the "plaster of Paris." It may readily be detected by its odor if we heat some of the "plaster of Paris" in the above experiment.)

Chalk + Hydrochloric Acid = Calcium Chloride + Carbonic Oxide + Water.*

Lime-water + Carbonic Oxide = Chalk + Water.*

Lime + Sal Ammoniac = Calcium Chloride + Water + Ammonia.

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* Some water was formed in these experiments in addition to the water of the original solutions.

APPENDIX.

Notes on the Experiments.

CHAPTER I. SECTION I.

Experiment 9, page 15.—If one is situated so that illuminating gas is at hand, a Bunsen burner, such as is used in laboratories, and which may be procured for forty-five cents, is the best thing to use for experiments which require heat. A piece of gas-tubing, $\frac{1}{4}$ inch internal diameter and long enough to reach from the nearest gas-jet to the burner upon the table, will be needed, and the very best quality will cost about thirteen cents a foot. If gas is not at hand, the next best thing is an alcohol lamp; an excellent one can be procured for forty-five cents, and alcohol should cost sixty cents a quart. Both the alcohol flame and the Bunsen burner flame possess the advantages of supplying a large quantity of heat and of producing no smoke.

Lamps which produce heat for experiments.

Test-tubes, six inches long by three quarters of an inch in diameter, cost thirty-five cents a dozen, and have such a variety of uses that one cannot well afford to be without them. They are calculated to endure sudden changes of temperature, but are easily broken by careless handling, since the glass is nearly as thin as paper.

Test-tubes.

Experiment 10, page 15.—A test-tube may be used to advantage in this experiment.

Allow the end of the lamp-lighter to project into the mouth of a test-tube which has been put into a tumbler of water to keep it cool (Fig. 34). In this way the vapor condenses so rapidly that a thimbleful of liquid may be obtained from three or four lamp-lighters made from brown paper. The test-tube containing the liquid may then be brought directly into the flame of a lamp, and a convenient way to hold it will be suggested by referring to Fig. 20, page 50. The liquid soon vaporizes, and pours forth from the mouth of the test-tube in such quantities as to support a large flame. The charred mass which is left at the close of the experiment can best be examined by breaking the tube; and, since it is a very difficult task to clean it, the tube will be willingly sacrificed.

Collecting liquid in a test-tube from lamp-lighters.

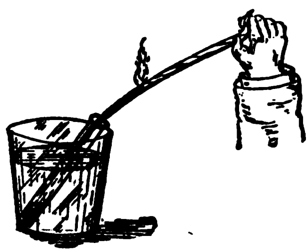

Fig. 34

By the following method we obtained as much as a tablespoonful of liquid from one sheet of a daily newspaper: About one quarter of the sheet at a time was rolled up and packed into the lower half of a test-tube (Fig. 35), through the stopper of which passed a short bent delivery-tube, which reached down into a small bottle immersed in a tumbler of water to keep it cool. In this way a large part of the vapor from the heated paper was condensed in the small bottle, and then sealed up and labelled, to be kept as a specimen.

Liquid from one sheet of newspaper.

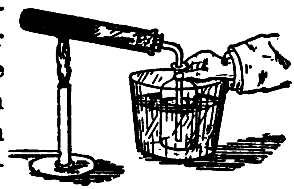

Fig. 35

Full directions for bending glass-tubing can be found in the author's Manual of Home-made Apparatus, page 4. The best glass-tubing should not cost over fifty cents a pound. The most useful size will be that which is from one eighth to three sixteenths of an inch internal diameter, and there will be at least twenty-five feet of it in a pound. The tubing can be bent in any kind of a flame; candle, kerosene lamp, alcohol lamp, or ordinary gas flame. The latter is the best.

Cost of glass-tubing.

Bending glass-tubing.

The best rubber stoppers, and the cheapest, cannot be purchased at the ordinary drug-stores. The best way is to order them by mail from some of the large houses, such as Messrs. Eimer & Amend of New York City, or Jas. W. Queen & Co., Philadelphia. They should always be "pure gum," and

Rubber stoppers.

although the first expense is considerable, they ar far the most satisfactory and the cheapest in the The stoppers may be purchased with one or with perforations. These will fit the tubing already m tioned, and, whenever the stoppers are to be used w out perforations, they are easily plugged with a l piece of wood or glass rod.

The stoppers are sold by weight, and should not over two dollars and seventy-five cents a pound.

Those sold by Eimer & Amend are numbered cording to the following table, which is given for convenience of those wishing to order by mail:

TABLE EXHIBITING PRICES AND SIZES OF RUBBER STOP ACCORDING TO NUMBER.

Number.	Diameter at Bottom.	Diameter at, Top.	Approxim Price Eac
00	$\frac{6}{16}$ inch	$\frac{8}{16}$ inch	2 cent
0	$\frac{7}{16}$ "	$\frac{10}{16}$ "	3 "
1	$\frac{9}{16}$ "	$\frac{11}{16}$ "	4 "
2	$\frac{10}{16}$ "	$\frac{12}{16}$ "	5 "
3	$\frac{11}{16}$ "	$\frac{14}{16}$ "	7 "
4	$\frac{12}{16}$ "	$\frac{15}{16}$ "	8 "
5	$\frac{14}{16}$ "	1 "	10 "
6	$\frac{15}{16}$ "	$1\frac{3}{16}$ "	14 "
7	$1\frac{2}{16}$ "	$1\frac{6}{16}$ "	20 "
8	$1\frac{4}{16}$ "	$1\frac{8}{16}$ "	23 "
9	$1\frac{6}{16}$ "	$1\frac{11}{16}$ "	31 "
10	$1\frac{9}{16}$ "	$1\frac{14}{16}$ "	39 "

Experiment 11, page 16.—The ashes obtained f a twelve-paged newspaper, according to the method of Experiment 11, could all be piled upon a good-sized tablespoon, and they were found to weigh one sixteenth of an ounce, while the paper from which they came weighed

Ashes f a twel page n paper.

and a half ounces, or forty times as much. They were sealed up in a small bottle, labelled, and kept as a specimen.

Query.—Is there any flame inside of a burning lamp-lighter?

The experiments of Sec. 1 furnish a good pretext for having reports made by pupils upon:

The uses of creosote.

The manufacture of paper and some of its various uses, such as making car-wheels, etc.

Tinctures, etc.

Information on such subjects will readily be found in a cyclopedia.

It should be particularly noted that the mineral matter found in paper is partly derived from the vegetable material of which the paper was made, and was taken from the soil by the plant, but in many cases much mineral matter is added to the pulp in the manufacture of paper.

CHAPTER I. SECTION II.

Experiment 15, page 19.—It may be necessary to heat the box quite a long time before vapor will be produced in sufficient quantities to catch fire. Whenever air and a combustible gas are mixed, the proportion of combustible in the mixture must reach a certain limit before burning is possible. Witness the fact that illuminating gas may flow into a room a long time where a light is burning without an explosion taking place. It was found in Experiment 55, page 41, that a

Relative quantities of gas and air for combustion.

mixture, in which the ratio of gas to air fell much *below one sixth,* was incapable of combustion.

Experiment 19, page 21.—The liquid is best obtained by the method described on page 77, and can be vaporized by heating it in a test-tube as described in note on Experiment 10, page 77.

Experiment 21, page 21.—It is noticeable that when a charcoal fire is blown much a flame is sometimes produced. This might be due to the fact that the wood was not thoroughly charred, i.e., the gaseous and liquid products had not all been driven off. It also might, in some cases, be due to the same cause that produces blue flames upon a fire of hard coal, which is nearly as pure carbon as charcoal.

Flame upon a charcoal fire.

The explanation can be found in any chemistry under carbon monoxide. Carbon when burned without a sufficient supply of oxygen gives rise to a gas composed of carbon and oxygen, but it does not contain as large a proportion of oxygen as it is capable of taking; hence it burns when it comes in contact with the air, if it is heated above its kindling temperature, i.e., it takes on the full complement of oxygen and becomes the gas which turns lime-water milky, or, as it was called in Chapter VI., carbonic oxide. It is generally called in chemistries carbon *di*oxide to distinguish it from the carbon *mon*oxide mentioned above. It is popularly known as carbonic acid gas, for no very good reason.

Carbon monoxide.

Carbon dioxide.

Experiment 22, page 22.—When a considerable quantity of ashes is needed, it is better to obtain them from an ordinary wood fire; or, if that is not convenient, they may be readily produced by piling kindlings on a fire shovel and allowing them to burn freely in the air. The ashes will need further roasting to dispose of all the carbon, and this may be accomplished by setting the shovel inside of the furnace or stove for a short time.

How to obtain a quantity of wood ashes.

Experiment 24, page 23, last paragraph.—We obtained an ounce vial half full of the liquid products, with the apparatus described on p. 78 for obtaining liquid from paper, by packing the lower half of the test-tube full of slivers of wood, taking care in heating not to melt the stopper, and, when the slivers were thoroughly charred, replacing them several times with fresh wood.

The cyclopædia will furnish material for reports upon:

The manufacture of charcoal and its uses.

The manufacture of wood vinegar and wood alcohol.

The manufacture of illuminating gas.

The manufacture of soap.

CHAPTER I. SECTION III.

Paraffine can be procured at eighteen cents a pound, or paraffine candles may be bought and melted over. It is much more agreeable than tallow, and has many other uses in the laboratory besides that of making candles.

Paraffine.

CHAPTER VI.

Experiment 74, page 59.—The gas formed by the burning paper is somewhat soluble in water, but unless the gas and water are shaken up together during the experiment there will be very little contraction of volume due to that cause.

Experiment 75, page 59.—After putting the phosphorus into the tube it should be inverted over the water as quickly as possible, so that the water may rise to take the place of *all* the oxygen which is used up: otherwise more air will go in to take its place, and the result will be too large a proportion of nitrogen. It is also essential that the tube should be brought down perpendicularly over the water at first, otherwise a portion of the air will be driven out by the water, and the result will be too small a proportion of nitrogen.

The experiment, if properly managed, will give very gratifying results.

Experiment 76, page 60.—Chlorate of potash is the familiar substance which is used in the form of tablets for sore-throat. It can be procured at any drug-store in the powdered condition, and should cost only a few cents an ounce. (A pound is worth about twenty-four cents.) An ounce of the powder will yield about *two gallons* of oxygen gas.

Cost of chlorate of potash.

Amount of oxygen yielded by one ounce.

the oil in the tumbler the "flashing" temperature may be determined.

Subjects for report:

Oil-wells.

The refining of oil.

Capillary attraction,—familiar illustrations showing how common and how important it is in nature.

The relation between coal-mines, oil-wells, and gas-wells.

CHAPTER II.

Cost of phosphorus.

Phosphorus costs only fifteen cents an ounce. It is rather light, and an ounce of it would suffice for performing the experiments of this book a great many hundred times. We use a piece about as large as a grain of rice for each experiment. It is kept in a small, wide-mouthed bottle, covered with water to prevent it from taking fire. When a piece is desired we cut it off with a penknife,—it cuts like wax,—and, piercing the point of the knife into the little piece which has been detached, transfer it to the place where it is to be used in the experiment. It is wholly unnecessary to be alarmed about its use.

How to handle phosphorus.

Cost of carbon bisulphide.

Carbon bisulphide, variously called bisulphide of carbon and bisulphuret of carbon, costs twenty cents a pound. It is a liquid, and a pound of it makes somewhat less than a pint in volume. Since it dissolves rubber it is used in a preparation for mending rubber shoes; hence the odor is

sometimes recognized at the shoemaker's. It also dissolves sulphur. Only a few drops are necessary for the experiments of this book.

Cost of ether.

Ether costs sixty-five cents a pound, which is considerably more than a pint. It is exceedingly convenient to have about the school-room for etherizing insects and other small animals to be kept as specimens. One need not hesitate to experiment with it, as it has no perceptible effect upon a human being under such circumstances. If the nose and mouth are covered with a towel or sponge saturated with it, and all the air that is breathed is drawn through this, unconsciousness will be produced in time.

Cost of wire gauze.

Experiment 38, page 33.—The wire-gauze used in this experiment and the next had about forty meshes to the inch, and cost forty-five cents a square foot. A piece six inches square was used both for this experiment and for making the lantern of the next.

Experiment 39, page 34.—The experiment is very successful if the gas is caught by "upward displacement" (see p. 45).

The bottle may be held inverted over any gas tip and the gas turned on. If the bottle is well filled with gas, the flame of the lantern will be extinguished for want of oxygen. If an explosive mixture is desired, the right proportions of air and gas may be procured by the method described on page 41, or by upward displacement, after a few repeated trials.

If illuminating gas is not in the school-building, a few drops of ether may be put into the bottle, which will soon fill it with a combustible vapor that will make the experiment equally successful. This may suggest that gasolene, a very volatile liquid which gives a combustible vapor, by means of heat or a current of air forced from a blower, is often made to supply a vapor which takes the place of illuminating gas in the lighting of streets and buildings.

The vapor of ether and gasolene as a substitute for illuminating gas.

Experiment 39 has also been successfully performed by using lamp-lighter smoke for the combustible gas.

Tapers can be procured for fifteen cents a dozen. The short argand-lamp chimney mentioned on page 83 is the best thing to use for the tube called for in the last paragraph of Experiment 39. If one has a candle with a very thick wick it is possible to have a flame at the top quite as large as that below.

Cost of tapers.

Experiment 43, page 37.—The experiment is performed by putting a few drops of carbon bisulphide into a tumbler. They will soon evaporate, and the vapor, being heavier than air, will fill the tumbler from below, crowding the air out above. Although this cannot be seen, it is made evident when a lighted match is brought to the mouth of the tumbler, for then the vapor immediately catches fire and burns with a pale-blue flame, which is characteristic of burning sulphur, and which gives the familiar odor. A yellow coating of unburned sulphur is deposited

upon the sides of the glass, just as carbon would be deposited from an ordinary flame. There is no danger of breaking the tumbler in the process.

For a method of performing Marsh's test see note on Experiment 85, page 95.

Subjects for report might be selected, such as:

The manufacture of phosphorus.
How sulphur is obtained.
The maufacture of matches.
The mining of coal.
The manufacture and uses of lamp-black.

CHAPTER III.

Experiment 51, page 40.—It is well to have the hole at least half an inch in diameter. We made the experiment more interesting by using an argand-lamp chimney and boring a hole* in the side with a wet file.

Experiment 52, page 40.—We also put a small piece of phosphorus upon a plate, or a piece of window-glass, or even upon the crayon box, lighted it, and then inverted a tumbler over it. The tumbler filled with white fumes, which slowly precipitated as a white powder, and the flame died out. After waiting a few moments we raised the tumbler, and as soon as the air entered, the

Burning phosphorus extinguished for want of air.

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* Full directions are to be found in the Manual of Home-made Apparatus, page 15.

phosphorus, being still heated above its kindling temperature, took fire. When the tumbler was replaced it was soon extinguished again.

Collecting an oxide of phosphorus.

After repeating this several times we had a considerable quantity of the white powder, which made a hissing noise when a drop of water was put upon it, and when it was dissolved in a little water the solution turned litmus-paper red.

This white powder, however, will have more interest in connection with Chapter VI. The observation which concerns us at present is that even phosphorus, although heated above its kindling temperature, cannot burn without air.

Phosphorus melted under water without catching fire.

In further illustration of this we put phosphorus into water and heated it until it melted, but it did not catch fire while the water covered it. We poured off the water, or siphoned it off, and when exposed to the air the phosphorus caught fire.

Melted phosphorus caught fire under water when air was conveyed to it.

A more startling illustration was furnished by blowing a stream of air from a bellows down upon the melted phosphorus under water, which gave us the satisfaction of seeing flashes of fire under water.

Cost of rubber cloth.

Experiment 55, page 41.—Rubber cloth, such as dentists use, can be procured for twenty cents an ounce. An ounce of it will contain from one to two square feet, according to thickness.

Experiment 56, page 41.—The tube was a short piece

of glass tubing, which we had nearly closed at the end, as described in Woodhull's Manual of Home-made Apparatus, page 9. This was put into the end of a piece of rubber tubing, because it is convenient to have a flexible tube and one with elastic walls. By keeping the cheeks filled out with air it is possible to keep a stream flowing continually through the blow-pipe, without a particle of variation, while respiration goes on naturally through the nose.

Paragraph four, page 42.—The bottle should at least have the capacity of a quart. It may be filled by upward displacement by holding it over the end of the gas-pipe. The tube which conducts the air should be at least a quarter of an inch internal diameter. Light the gas at the mouth of the bottle and slowly pass up into it the tube bringing a stream of air forced quite gently from the bellows.

A very pale-blue flame will be carried up into the bottle. If the bottle is dry, moisture will be noticed to gather upon it, which is of interest in connection with Experiments 63–65, Chapter IV.

Reports upon the construction of various forms of kerosene lamps, gained from a careful examination of the lamps themselves, are in place here.

CHAPTER IV.

Experiment 60, page 46.—This requires a tall, narrow box, or the air will pass in fast enough to support the flame. In case a wide-mouthed tin box is used, cover

it for a short time, and then raise the cover and quickly thrust in a glowing splinter.

In order to catch a sufficient quantity of the gas in the bottle to extinguish a flame, we closed the mouth of the bottle down upon the mouth of the box pretty tightly, and left it for quite a long time.

Experiment 61, page 47.—If illuminating gas is in the school building, some of it may be caught in a bottle, and then some lime-water poured in and shaken to show that this gas will not turn it milky. Now bring a flame to the mouth of the bottle, and after it has ceased to burn shake again, when the lime-water will become very milky. Or, in case illuminating gas is not at hand, ether vapor will give the same results, and may be obtained as described on p. 86 by putting a few drops of the liquid ether into the bottle.

CHAPTER V.

Experiment 67, page 52.—The flame must be a very large one, and there should be no other draughts of air in the vicinity to interfere with the experiment.

Figure 22, page 54.—We made a piece of apparatus, to represent what is shown in Fig. 22, out of a cigar-box, tacking a pane of window-glass on the front and back, and using paper-smoke to trace the currents. A taper was placed at *g*. The smoke on entering was carried directly to the top of the room, and after spreading over the top settled gradually, and was carried out at *f*. It

was surprising how rapidly the room was cleared after it had been filled so densely as to make it impossible to see through it.

Experiment 69, page 55.—A very ordinary pair of shears will answer well for cutting tin and wire, and, although it will spoil them for cutting paper or cloth, they may be used for the other purpose an indefinite time.

Experiment 70, page 55.—The rubber cloth mentioned on page 88 may be used, or the rubber bag cut from a toy balloon, costing ten cents; or rubber bags may be procured from the toys known as "squalkers," costing from one to five cents.

Experiment 71, page 56.—By cautiously passing a bottle back and forth through a flame it may be made very hot without breaking it. Some little time is required to transmit this heat to the air inside, since glass is a very poor conductor, and so also is air. We are dependent upon currents of air set up inside of the bottle to diffuse the heat throughout the mass. It will also be found to require a long time to cool, but when the glass is partially cooled water may safely be poured upon it, and the drawing in of the rubber will be very striking. The success of the experiment depends upon getting the rubber tied on *air-tight.*

Figure 25, page 57.—The stopper in the upper bottle must be of good rubber, and must fit the tube very tightly so as not to leak air.

If a one-ounce narrow-mouthed bottle is used, the tubing may be made to fit the neck tightly by drawing over it a short piece of soft rubber tubing without using any other stopper. The scale can be made on a strip of white paper divided into inches and fractional parts. The value of these divisions in degrees may be determined by placing this apparatus near some other thermometer under various conditions of temperature and comparing them.

If the lower end of the tube be made to pass through a hole in an ordinary cork into a fair-sized bottle containing the liquid, no other support for the apparatus will be needed. For working holes through common corks, cork-borers, consisting of brass tubes of different sizes and terminating at one end with sharp cutting edges, are very useful, and are sold in nests numbered according to size. A set of three (Nos. 1–3) will be found very useful, and will cost sixty cents. With these one can make holes to fit the glass tubing already mentioned. However, the same thing may be accomplished with a small round file. Use the sharp end that is intended to go into the handle, and by a twisting movement a hole may be made which may be finished up with the file part. Inasmuch as ordinary corks are seldom air-tight, and the hole which you have made will not fit the tube air-tight, the atmospheric pressure will be exerted upon the liquid in the bottle quite as well as in the tumbler of Fig. 25.

Cork-borers.

CHAPTER VI.

Experiment 74, page 59.—The gas formed by the burning paper is somewhat soluble in water, but unless the gas and water are shaken up together during the experiment there will be very little contraction of volume due to that cause.

Experiment 75, page 59.—After putting the phosphorus into the tube it should be inverted over the water as quickly as possible, so that the water may rise to take the place of *all* the oxygen which is used up: otherwise more air will go in to take its place, and the result will be too large a proportion of nitrogen. It is also essential that the tube should be brought down perpendicularly over the water at first, otherwise a portion of the air will be driven out by the water, and the result will be too small a proportion of nitrogen.

The experiment, if properly managed, will give very gratifying results.

Experiment 76, page 60.—Chlorate of potash is the familiar substance which is used in the form of tablets for sore-throat. It can be procured at any drug-store in the powdered condition, and should cost only a few cents an ounce. (A pound is worth about twenty-four cents.) An ounce of the powder will yield about two gallons of oxygen gas.

Cost of chlorate of potash.

Amount of oxygen yielded by one ounce.

Black oxide of manganese—also in powdered condition—costs even less than the chlorate of potash.

Experiment 79, page 62.—When a small piece of charcoal is needed, it may be obtained by burning a sliver of wood freely in the air. After the gaseous and liquid products have been disposed of, the flame will go out of its own accord, leaving some charcoal at the end, as when a match is burned. This charred end with a spark upon it may be thrust into the bottle of oxygen without the use of the combustion spoon.

The simplest way to obtain a little charcoal.

It is not necessary to cover the bottles of oxygen in this and the following experiments. Oxygen has about the same weight as air, and it diffuses out of the bottle very slowly. The heat formed will not cause sufficient currents to interfere with the success of the experiment.

Experiment 80, page 62.—Sulphur in rolls, sometimes called roll brimstone, will cost, at most, not more than ten cents a pound.

Cost of sulphur.

Experiment 82, page 63.—To obtain melted sulphur for the end of the watch-spring, take a piece of roll brimstone and bring a flame to one end long enough to melt it, and then apply it to the string on the watch-spring as you would use sealing-wax.

In order to get enough iron rust on the sides of the bottle to show well, take a bottle which has a capacity of at least a quart, and a narrow mouth is preferable.

A watch-spring is so thin that while it is melting and burning at one end you may hold it a few inches from

deposited upon the cool surface with its peculiar metallic lustre.

Last sentence, page 65.—We showed that carbonic oxide was a product of fermentation by filling a tumbler with water, adding a teaspoonful of molasses and a few bits of a yeast-cake, and then inverting it in a saucer containing enough water to seal the mouth. This was put in a warm place, such as we should select for raising bread, and the gas collected quite rapidly in the tumbler and displaced the water. A lighted match was extinguished by the gas thus caught in the tumbler, and it turned lime-water milky.

Carbon dioxide, alcohol, and vinegar obtained by putting yeast into molasses and water.

The liquid which remained in the saucer was kept many days, and in time had a decided odor of alcohol, but later exhibited a very strong vinegar odor.

Experiment 86, page 68.—Cut sugar is a very convenient form to use. While the sugar was heating, a smoke, similar to that noted in various experiments in Chapter I, was seen to arise, and, when a lighted match was brought near, it caught fire.

A combustible gas from sugar.

Experiment 87, page 69.—Sulphuric acid, also frequently called "oil of vitriol," is an exceedingly common article of commerce. · Nearly a million tons of it are manufactured annually in Great Britain, and about one third as much is produced in the United States each year.

Cost of sulphuric acid.

The common commercial acid, as it is called, which is sufficiently good for all the experiments mentioned in this book, costs about ten cents a pound, or in half-gallon bottles, weighing about nine pounds, five cents a pound.

Small drug-stores are apt to keep only that which has been refined for medicinal purposes, and which is worth about twenty cents a pound; or, if they keep the commercial, it is frequently allowed to get as black as ink by contact with a common cork or wood. It should be kept in a glass-stoppered bottle.

If one has difficulty with Experiment 87, it is probably due to the fact that the acid is poured in too rapidly, or the sugar solution is not sufficiently concentrated. We pour in perhaps half a teaspoonful at a time, and then stir very *thoroughly* before adding more. It may be stirred with a stick, if a glass rod or tube is not at hand, in which case it will be noticed that the stick is very much charred by the acid.

Cost of sal-ammoniac.

Experiment 88, page 70.—Sal-ammoniac, also called ammonium chloride, is a very common substance, being used very much for electric batteries and other purposes. It costs, in the powdered condition, about eighteen cents a pound. The lime is such as is used for whitewashing houses, and, however poor it may be, it will probably yield ammonia gas when put with ammonium chloride.

But if freshly burned lime, the so-called quick-lime, can be procured, take a small lump of it and put a little water upon it. The water will be absorbed into the

lime, which will get very hot and swell up and fall to a dry powder. Now, if ammonium chloride be put with this freshly slaked lime, large quantities of ammonia gas will be given off, and the mixture will get very moist. We have made excellent quicklime by roasting a lump of carpenter's chalk in the kitchen fire for a short time.

How to make quicklime from chalk.

Ammonia gas is very soluble in water, and it is this solution which is sold under the name of Aqua Ammonia. It is worth about fifteen cents a pound.

Cost of ammonia.

Hydrochloric acid is also a gas which is very soluble in water. This solution goes by various names, such as Hydrochloric Acid, Chlorhydric Acid, Hydrogen Chloride, and Muriatic Acid.

The common commercial acid, which is quite good enough for use in these experiments, costs, the same as sulphuric acid, ten cents a pound, or, in half-gallon bottles, five cents a pound.

Cost of hydrochloric acid.

Experiment 90, page 71.—Calcium chloride is formed in Experiment 88 by the combination of freshly slaked lime with ammonium chloride. It is also made in Experiment 91 by the combination of chalk with hydrochloric acid, and may readily be obtained as described there. If the liquid before evaporation is not perfectly clear, the product after evaporation will be of a dirty color. This may be obviated by pouring the liquid through filter-paper, or even straining it through several thicknesses of cotton cloth. The calcium chloride will then be pure white.

Calcium chloride in the crude condition may be purchased for ten cents a pound; if purified, for forty cents a pound. It will be noticed that when calcium chloride dissolves in water heat is produced.

Cost of calcium chloride.

It will readily be conceded that the conducting of *observation lessons by experimental methods in primary and grammar classes* is well worth a little expense and trouble. The author believes that in the course outlined by this book both have been reduced to such a trifling amount that they no longer present any appreciable difficulties. Careful estimates show that the expense of giving these lessons the first year need not exceed five dollars, and, since much of the material will remain as permanent equipment, the cost thereafter will not exceed two dollars a year.

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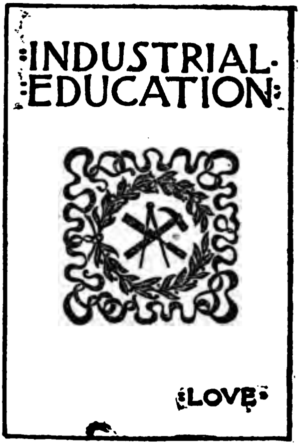

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